Illinois Department of Transportation
2300 South Dirksen Parkway / Springfield, Illinois / 62764

BDE PROCEDURE MEMORANDUM

NUMBER: 64-08

SUBJECT: Portland Cement Concrete Inlay or Overlay

DATE: August 1, 2008

This memorandum provides guidance for a pavement rehabilitation strategy that involves a 3.0 to 6.0 inch portland cement concrete (PCC) inlay/overlay. This guidance provides additional information to supplement BDE Manual Chapter 53 and will be included in a future manual update.

Background

The stopping, starting, standing, and turning actions of vehicles at intersections or other locations may create rutting and other severe conditions for pavement structures with hot mix asphalt (HMA) surfaces. The volume and type of vehicles may also distress HMA surfaces. Standing water in ruts (i.e. from rain events) may create a hydroplaning hazard. In addition, snow and ice left in the ruts after snowplowing may be hazardous to the traveling public. Therefore, a PCC inlay/overlay may be a better alternative than HMA. The PCC inlay/overlay has no risk for rutting and a longer service life may be achieved.

A PCC inlay/overlay consists of placing a thin concrete layer on an existing HMA surface. Construction of an inlay/overlay includes milling the existing rutted HMA to correct longitudinal profile and cross-slope irregularities and providing a surface for bonding of the overlay. A PCC inlay/overlay may be considered as an alternative at intersections or other locations where HMA overlays have shown a tendency to rut or have shortened performance lives.

Synthetic fibers are required when the inlay/overlay is 4.0 inches or less, and optional when it exceeds 4.0 inches. The synthetic fibers currently used are much different from the fibers originally used in inlay/overlay projects. The original fibers used were mainly to prevent plastic shrinkage cracks. The new fibers will provide structural reinforcement, which will increase flexural toughness and cracking resistance.

These procedures do not apply to a thickness greater than 6.0 inches which is considered an unbonded inlay/overlay.

Applicability

These guidelines have been prepared for a rehabilitation strategy that involves a 3.0 to 6.0 inch PCC inlay/overlay bonded to a pavement structure that has a HMA surface. This rehabilitation strategy has been previously known as ultrathin whitetopping.

These guidelines may be used to evaluate pavement at an existing intersection or other locations to determine if use of a PCC inlay/overlay is feasible and constructible. These guidelines also contain design steps needed to successfully complete this option. A PCC inlay/overlay requires a thorough review of the existing pavement structure, as well as close attention to utility, profile, and elevation adjustments. This technique requires a bonding action to the underlying HMA surface and multiple joints at an early age to control cracking and curling stresses within the inlay/overlay.

These guidelines are to be followed to: (a) review the existing pavement structure, (b) identify design considerations, and (c) prepare a request for review and approval of a PCC inlay/overlay system.

Limitations

Performance of PCC inlay/overlay sections can be variable because of the underlying pavement structure. The designer should consider the general constructability of a PCC inlay/overlay at the selected location. The existing HMA layer that is to remain in place shall be a minimum of 2.5 inches thick. If a portion of the PCC inlay/overlay in excess of five percent will be bonded directly to bare concrete, brick or other old slabs of concrete, this rehabilitation method shall not be used. The five percent limitation is to allow for existing concrete patches or other existing pavement features. Construction is also hindered by complicated geometrics, utility obstructions, traffic demand and condition of the existing pavement.

The term PCC inlay can be defined as a very minor or no change in grade; and, as such, could limit its use in areas where profile adjustments would be limited, such as with existing curb and gutter sections. A PCC overlay would be used where profile grade adjustments are feasible.

This alternative rehabilitation strategy shall apply to Class I, II, III, and IV pavements, but shall not be used for federal-aid interstates or when the traffic factor (based on the rigid pavement equations) exceeds 5.0.

Procedures

All proposed PCC inlay/overlay projects must be submitted to the Bureau of Design and Environment for approval. The request should be documented in a “PCC Inlay/Overlay Project Request Report” and should include the following:

a) a report of the preliminary and detailed pavement investigations;
b) existing and proposed cross sections;
c) existing and projected traffic information;
d) construction sequencing and proposed traffic control;
e) a cost analysis for each rehabilitation alternative; and
f) a summary on why a PCC inlay/overlay is the preferred method of rehabilitation over other alternatives.

Guidelines regarding the items to be included in the report and other design details for a PCC inlay/overlay are discussed in the following sections. The designer should review all requirements and do preliminary calculations to check the feasibility of this process before proceeding with some of the detailed investigations.

Review of Existing Pavement Structure

A thorough investigation of the existing pavement structure should be conducted. The purpose of this investigation is to determine if the section in question is suitable for a PCC inlay/overlay. It is essential that only appropriate sections be selected for this rehabilitation option.

(1) Preliminary Pavement Investigation, Design and Traffic Factor Considerations

The designer should research past rehabilitation attempts as well as future plans for the area that surrounds the intersection/roadway. Research of past rehabilitation attempts will provide information on why past rehabilitation methods have not performed as desired. Insight into future plans for the pavement and area surrounding the project may influence the design of the rehabilitation. The designer should check to see if any of the limitations of this application apply.

If it appears that a PCC inlay/overlay can be constructed, then a detailed pavement investigation is necessary to verify the constructability of the inlay/overlay.

(2) Detailed Pavement Investigation

Upon completion of the preliminary investigation, a detailed pavement coring plan should be developed and administered. In general, cores will be taken to represent all pavement cross sections and all locations within the project. A document with guidelines for material sampling entitled “Guidelines for Material Sampling and Testing of Existing Bituminous Concrete Pavements and Overlays” is available through the Bureau of Materials and Physical Research. The coring plan should be completed to specifically address the following points:

- Total pavement thickness and thickness for each layer of concrete or HMA detected.
- Condition, tensile strength, and presence of stripping for each HMA layer.
- Condition, compressive strength (optional), presence of D-cracking, and presence of alkali-silica reaction for each concrete layer.
- Identification of locations where patching or alternative rehabilitation methods are recommended.

In addition to the coring plan, a general inspection of project limits should be completed. In general, the inspection will address items such as geometrics, drainage, utilities, and surface abnormalities. More specifically, the inspection should address the following points:

- Intersection of pavement crowns (multi-leg intersections).
- Location of drop inlets.
- Location of loop detectors for traffic signals (detector loops would be installed into the milled surface).
- Location of sewer manholes, water valves, and all other utility obstructions.
- Location of existing surface patches.
- Location of high severity distresses.
- Location of HMA rutting exceeding 0.35 inch.
- Clearances for overheads.

(3) Existing and Projected Average Daily Traffic

An accurate count of the existing Average Daily Traffic (ADT) with a breakdown of percentages for passenger vehicles, single unit, and multiple unit trucks should be performed. In addition, estimates for the projected ADT and classification breakdown should be developed for the design period.

Upon completion of coring and inspection procedures, and collection of traffic data, a report should be created to document this information.

<u>Identify Design Considerations</u>

There are several design issues that must be considered before a PCC inlay/overlay project can be submitted for review and approval. A list of issues that may be resolved prior to the submittal of a design is as follows:

(1) Design Period

The design period to be used for this rehabilitation strategy is 15 years.

(2) Cost Alternatives

A cost analysis of several different rehabilitation options is required. Cost analyses include initial construction cost, annual maintenance cost, and expected lifespan of the rehabilitation option. However, the annual maintenance cost information involving an inlay/overlay using the new stronger synthetic fibers is currently limited. It is suggested to contact the Bureau of Materials and Physical Research for assistance. Cost alternatives may also include various options within the same rehabilitation technique.

(3) Drainage Considerations

Maintaining proper drainage through design and during construction is important. During construction, maintaining drainage is especially critical for projects that include an inlay.

(4) Pavement Preparation and Profile

The existing pavement surface shall be milled to correct longitudinal profile and cross-slope irregularities, remove any foreign materials, and remove oxidized HMA from the surface. Milling will also increase the surface area for bonding of the PCC inlay/overlay. If patching will be required on the project, the designer needs to keep in mind that the five percent limitation for bonding the PCC inlay/overlay to concrete still applies. Refer to "Preliminary Pavement Investigation, Design and Traffic Factor Considerations" under the "Review of Existing Pavement Structure" section of this Procedure Memorandum.

(5) Thickness Design and Joint Spacing

The PCC inlay/overlay thickness design is based on traffic factor, underlying HMA thickness, panel size, and fibers/no fibers. The inlay/overlay shall be 3.0 to 6.0 inches with 0.5 inch increments allowed.

The traffic factor shall be determined according to the applicable equation for each pavement class using the rigid pavement Traffic Factor Equations. Based on the traffic factor, the thickness of the underlying HMA material, panel size, and fibers/no fibers, the PCC inlay/overlay thickness may be determined from the tables in Attachment A. In lieu of the tables, a computer program is available from the Bureau of Design and Environment to input the traffic factor, the thickness of the underlying HMA material, panel size, and fibers/no fibers. A resulting thickness is then calculated and rounded up to the nearest 0.5 inch.

A key to the success of a PCC inlay/overlay is longitudinal and transverse joints. These joints are hand tooled into plastic concrete or sawed into hardened concrete to provide stress relief induced by drying shrinkage and curling of concrete. Hand tooled joints are not used on mainline pavement with a posted speed limit greater than 40 mph because they may not be as smooth as a sawed joint, resulting in a rougher ride. The joints should be laid out on a regular pattern for both longitudinal and transverse directions (to form squares) based on the spacing from the tables in Attachment A. No skewed joints will be allowed.

Transverse and longitudinal joints should be laid out to match joints, utility obstructions, and geometrics of the existing pavement when PCC pavement is exposed during milling. When feasible, longitudinal joints should be laid out to avoid the wheel path areas of the traveling lanes. The layout of all transverse and longitudinal joints should be detailed on the plan sheets.

The cost of sawing may significantly influence the cost of an inlay/overlay. A thicker inlay/overlay may be more economical than a thinner one because the greater thickness may increase the joint spacing, resulting in less sawing. In addition, the use of synthetic fibers for inlays/overlays greater than 4.0 inches may be more economical than inlays/overlays without them because the synthetic fibers may increase the joint spacing. Again, the amount of sawing is reduced.

(6) Final Finish

A rough broom final finish struck perpendicular to the direction of traffic flow shall be used in place of a Type B final finish at all locations with a posted speed limit of 40 mph or less. The rough broom finish shall be used across the entire surface area of the inlay/overlay including any hand tooled joints.

The special provision for “Variable Spaced Tining (BDE)” shall apply at all other locations.

(7) Traffic Control

The control of traffic through the project must be considered and well established prior to time of construction. The best alternative for traffic control is to completely close the project to traffic. This alternative may be difficult for urban projects; however, somewhat easier for rural projects. If closure to traffic is not possible, traffic control must be established that will effectively move traffic through the project with minimal disruption to construction operations and traffic flow. Traffic control that can be left unattended overnight must be anticipated for each stage of construction.

(8) Construction Staging

Construction staging for a PCC inlay/overlay project must be considered with respect to the construction timeframe and traffic flow through the project. The project must be staged in such a way that continuous traffic flow will be maintained. Construction staging must also consider the geometrics of the project and any lane to lane drop off restrictions that may be present with the overlay thickness.

These inlays/overlays have a traffic opening strength of 550 psi flexural or 3,000 psi compressive. The current PCC mix design specified may obtain the opening strength in as little as three days if properly proportioned. If the inlay/overlay must be opened to traffic in a shorter time frame, consult the District materials office for an acceptable high-early-strength PCC concrete mixture.

Request for Review and Approval

Upon completion of the PCC inlay/overlay investigation, the completed "PCC Inlay/Overlay Project Request Report" should be submitted to the Bureau of Design and Environment for review and approval.

Interim Engineer of Design and Environment EE Han

Attachments

The Bureau of Design and Environment has a computer program available at www.dot.il.gov/desenv/pdp.html to design PCC inlays/overlays. An alternative method for design is to use the tables provided in this attachment which were created using the computer program. The following default values were used as design inputs. If the program is used in lieu of the tables, the PCC Inlay/Overlay Project Request Report must include copies of the screens from the program indicating the inputs used for the design.

Design Inputs:

E_{AC} = 350,000 psi
E_C = 3,600,000 psi
MOR = 750 psi
k = 100 pci
$CTE = 5.5 \times 10^{-6}$ in./in./°F
P_{cr} = 20%
R = 85%
ΔT = -1.4 °F/in.
% Time = 58%

Where:

E_{AC} = Elastic Modulus of HMA Layer
E_C = Elastic Modulus of PCC Overlay or Inlay
MOR = Modulus of Rupture
k = Modulus of Subgrade
CTE = Coefficient of Thermal Expansion
P_{cr} = Percent of Panels with Cracking
R = Reliability Factor
ΔT = Temperature Gradient
% Time = Occurrence of Temperature Gradient

The following list defines the variables shown in the tables.

$R_{150,3}$ = Residual Strength Ratio (percent); where the net deflection is calculated as $L/150$ (L = span length) and is limited to 3 mm
h_{ac} = Thickness of existing hot-mix asphalt remaining after milling
h_c = Thickness of new PCC inlay/overlay
L = Joint spacing for longitudinal and transverse directions

PCC Inlay/Overlay Thickness Design Charts

With Synthetic Fibers ($R_{150,3}$ = 20%)

h_{ac} = 2.5 in.

Design Parameters		
Traffic Factor *L* = 48 in.	**Traffic Factor *L* = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
---	---	3
≤ 0.065	---	3.5
≤ 0.7	---	4
≤ 5	≤ 0.05	4.5
≤ 5	≤ 0.27	5
≤ 5	≤ 1.2	5.5
≤ 5	≤ 4.5	6

h_{ac} = 3.0 in.

Design Parameters		
Traffic Factor *L* = 48 in.	**Traffic Factor *L* = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 0.025	---	3
≤ 0.25	---	3.5
≤ 2.5	≤ 0.02	4
≤ 5	≤ 0.12	4.5
≤ 5	≤ 0.6	5
≤ 5	≤ 2.5	5.5
≤ 5	≤ 5	6

h_{ac} = 3.5 in.

Design Parameters		
Traffic Factor *L* = 48 in.	**Traffic Factor *L* = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 0.14	---	3
≤ 1.3	≤ 0.011	3.5
≤ 5	≤ 0.06	4
≤ 5	≤ 0.35	4.5
≤ 5	≤ 1.5	5
≤ 5	≤ 5	5.5
≤ 5	≤ 5	6

Without Synthetic Fibers ($R_{150,3}$ = 0%)

h_{ac} = 2.5 in.

Design Parameters		
Traffic Factor *L* = 48 in.	**Traffic Factor *L* = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 0.042	---	4.5
≤ 0.15	---	5
≤ 0.45	≤ 0.014	5.5
≤ 1	≤ 0.033	6

h_{ac} = 3.0 in.

Design Parameters		
Traffic Factor *L* = 48 in.	**Traffic Factor *L* = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 0.09	---	4.5
≤ 0.31	---	5
≤ 0.82	≤ 0.023	5.5
≤ 1.6	≤ 0.05	6

h_{ac} = 3.5 in.

Design Parameters		
Traffic Factor *L* = 48 in.	**Traffic Factor *L* = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 0.23	---	4.5
≤ 0.67	≤ 0.016	5
≤ 1.6	≤ 0.04	5.5
≤ 2.9	≤ 0.083	6

PCC Inlay/Overlay Thickness Design Charts

With Synthetic Fibers ($R_{150,3}$ = 20%)

h_{ac} = 4.0 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 1	---	3
≤ 5	≤ 0.042	3.5
≤ 5	≤ 0.21	4
≤ 5	≤ 1.1	4.5
≤ 5	≤ 4.5	5
≤ 5	≤ 5	5.5
≤ 5	≤ 5	6

h_{ac} = 4.5 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 0.037	3
≤ 5	≤ 0.19	3.5
≤ 5	≤ 0.86	4
≤ 5	≤ 4	4.5
≤ 5	≤ 5	5
≤ 5	≤ 5	5.5
≤ 5	≤ 5	6

h_{ac} = 5.0 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 0.22	3
≤ 5	≤ 0.95	3.5
≤ 5	≤ 4.2	4
≤ 5	≤ 5	4.5
≤ 5	≤ 5	5
≤ 5	≤ 5	5.5
≤ 5	≤ 5	6

Without Synthetic Fibers ($R_{150,3}$ = 0%)

h_{ac} = 4.0 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 0.63	≤ 0.012	4.5
≤ 1.6	≤ 0.033	5
≤ 3.4	≤ 0.075	5.5
≤ 5	≤ 0.14	6

h_{ac} = 4.5 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 1.9	≤ 0.03	4.5
≤ 4.2	≤ 0.07	5
≤ 5	≤ 0.16	5.5
≤ 5	≤ 0.26	6

h_{ac} = 5.0 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 0.077	4.5
≤ 5	≤ 0.16	5
≤ 5	≤ 0.3	5.5
≤ 5	≤ 0.48	6

PCC Inlay/Overlay Thickness Design Charts

With Synthetic Fibers ($R_{150,3}$ = 20%)

h_{ac} = 5.5 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 1.5	3
≤ 5	≤ 5	3.5
≤ 5	≤ 5	4
≤ 5	≤ 5	4.5
≤ 5	≤ 5	5
≤ 5	≤ 5	5.5
≤ 5	≤ 5	6

h_{ac} = 6.0 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 5	3
≤ 5	≤ 5	3.5
≤ 5	≤ 5	4
≤ 5	≤ 5	4.5
≤ 5	≤ 5	5
≤ 5	≤ 5	5.5
≤ 5	≤ 5	6

Without Synthetic Fibers ($R_{150,3}$ = 0%)

h_{ac} = 5.5 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 0.21	4.5
≤ 5	≤ 0.4	5
≤ 5	≤ 0.67	5.5
≤ 5	≤ 0.95	6

h_{ac} = 6.0 in.

Design Parameters		
Traffic Factor L = 48 in.	**Traffic Factor L = 72 in.**	**Inlay/Overlay Thickness, h_c (in.)**
≤ 5	≤ 0.62	4.5
≤ 5	≤ 1	5
≤ 5	≤ 1.5	5.5
≤ 5	≤ 1.9	6

Design Input Definitions

R_{150}^{150} **= Residual Strength Ratio**—The residual strength ratio of a flexural beam specimen at net deflection $L/150$ with span length L = 150 mm, tested according to Illinois Modified ASTM C 1609. The specified minimum is 20 percent using synthetic structural fibers, assume 0 percent if not. Comment: May also be referred to as $R_{150,3}$, indicating 3-mm net deflection.

L **= Panel Size**—The transverse/longitudinal PCC inlay/overlay panel joint spacing. Either 48-in. or 72-in.

h_{ac} **= Thickness of remaining HMA layer**—The remaining thickness of the in situ HMA pavement underlying the PCC inlay/overlay after milling.

h_c **= Thickness of PCC inlay/overlay**—The design thickness of the PCC inlay/overlay based on traffic factor, underlying HMA thickness, panel size, and inclusion of fibers. The inlay/overlay shall be 3.0 to 6.0 inches with 0.5 inch increments allowed.

E_{AC} **= Elastic Modulus of HMA Layer**—An elastic modulus of 100,000 psi represents a poor condition of asphalt pavement (e.g., an old, severely fatigue cracked). An elastic modulus of 350,000 psi (default input value) represents a moderate condition with some level of structural distresses. An elastic modulus of 600,000 psi represents a good condition with only surface distresses such as rutting, shoving, or weathering that can be mostly eliminated by cold milling.

E_{C} **= Elastic Modulus of PCC Overlay or Inlay**—For a 4,000 psi compressive strength concrete, the elastic modulus according to standard ACI correlation ($57{,}000\sqrt{f_c'}$) is approximately 3,600,000 psi (default input value).

MOR **= Modulus of Rupture**—Considering a required minimum flexural strength (3-point bending) and 90 percent confidence level, the mean strength at 14 days needs to be between 680 and 740 psi for a coefficient of variation of 15 and 20 percent, respectively. The design software requires (as an input) the mean design strength (default input value 750 psi), not the minimum specified strength.

k **= Modulus of Subgrade**—The modulus of subgrade reaction, k, incorporates any type of material below the HMA pavement and therefore can be considered a composite value. The k value has been found to have negligible effects (from 50 pci to 200 pci; default input value 100 pci) on UTW design.

CTE **= Coefficient of Thermal Expansion**—The typical coefficient of thermal expansion, *CTE*, value for concrete produced in Illinois is 5.5×10^{-6} inches/inch/°F (default input value).

R **= Reliability Factor,** P_{cr} **= Percent of Panels with Cracking**—According to AASHTO, 80 percent is the minimum recommended reliability for a rural interstate, while 85 percent is the minimum recommended reliability for an urban interstate. A conservative reliability R of 85 percent and a 20 percent cracking P_{cr} are recommended for this procedure.

ΔT **= Temperature Gradient,** ***% Time*** **= Occurrence of Temperature Gradient**—An equivalent temperature gradient of -1.4 °F/inch occurring 58 percent of the time was determined to produce the same amount of fatigue damage as the sum of all the individual temperature gradient damages.